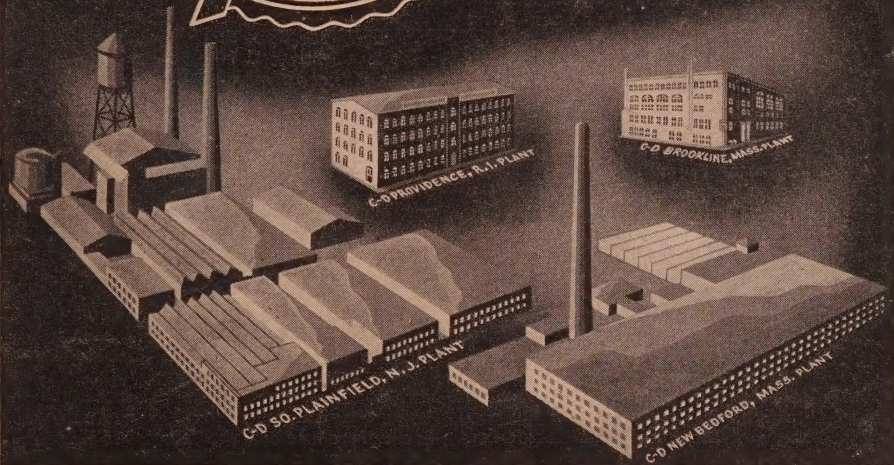


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DISTORTION, ITS MEANING AND MEASUREMENT

In the last few years, a great deal has been written about distortion. But not all of this material has been understandable to the amplifier serviceman. Few authors have made it clear what distortion is and how it may be measured. In the final analysis, it is the serviceman who must do the job of restoring amplifiers to full operating efficiency. We feel, therefore, that we should explain the subject for his benefit and drop as many engineering frills as possible. This article aims to define distortion and to explain its qualitative and quantitative measurement.

What is distortion? In simple language, it is the disfiguring of a signal as it passes through an amplifier. If a certain tone (signal) is fed into an amplifier, the same tone should come out, only louder. When distortion is present, the original tone comes out of the amplifier mixed with one or more higher-pitched tones (harmonics or "overtones") which were not present in the original tone. This causes the amplified tone to sound unnatural. It may sound harsh when the amount of distortion is large. When we check distortion, we simply measure the percentage of these undesired harmonics.

In addition to establishing the amount of distortion, a distortion test should show at which point within the amplifier the distortion begins. There are a few simple (**qualitative**) tests for distortion which may be made quickly by the serviceman. These tests involve little or no calculation and require few, if any instruments. They usually serve only to establish the fact that distortion is present, but do not show the amount or kind. Their usefulness therefore is limited. The best distortion tests are **quantitative**. That is, they are concerned with **how much** distortion is present. There are several methods of making quantitative

distortion tests. Each of these methods requires either special instruments, calculations, or a combination of instrument readings and calculations. Both qualitative and quantitative tests will be described in this article.

The Nature of Distortion

Three types of distortion ordinarily are encountered in audio amplifiers. These are **phase distortion**, **frequency distortion**, and **amplitude distortion**. It is amplitude distortion which is met most frequently and is of greatest importance in audio amplifier maintenance. Some authors refer to this same kind of distortion as **non-linear distortion**.

In order to see how amplitude distortion disfigures a signal as the latter passes through an amplifier, let us study Figures 1 and 2. For convenience in each instance, we have taken 1,000 cycles as the fundamental frequency of the signal fed into the amplifier. This signal is represented by the sine waves in Figures 1(A) and 2(A). In each case, the signal leaves the amplifier enlarged (amplified), as shown by 1(C) and 2(C). However, in Figure 1 a 2nd harmonic signal (2,000 cycles) has been generated within the amplifier and has been added to the output signal. And in Figure 2, a 3rd harmonic (3,000 cycles) has been set up and added. Figures 1(C) and 2(C) therefore represent distorted output signals.

Figures 1(C) and 2(C) show the actual pictures of distorted signals which we may see on an oscilloscope screen when the scope is connected to the amplifier output terminals. Notice, from Figure 1(C) that the 2nd harmonic affects only the top (positive) peaks of the output signal. Also, notice from 2(C) that the 3rd harmonic affects both peaks. This is a useful fact to remember, since it helps the

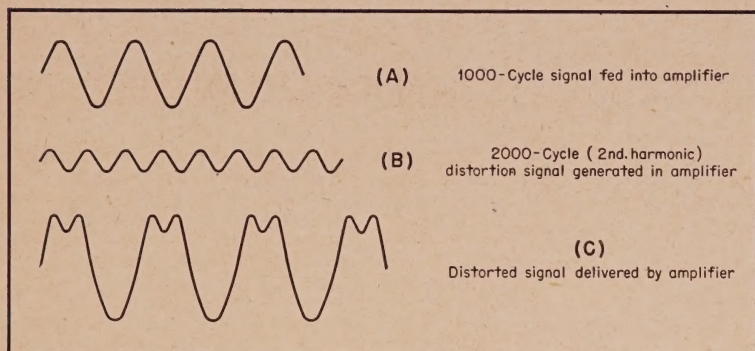


Fig. 1. Pronounced 2nd. harmonic distortion.

operator to identify roughly the type of distortion: **Even-numbered harmonics (2nd, 4th, 6th, etc.)** always affect the **positive peak**, as shown in Figure 1(C), while **odd-numbered harmonics (3rd, 5th, 7th, etc.)** always affect **both peaks similarly**. For these reasons, odd-numbered harmonics are said to produce symmetrical distortion; and even-numbered harmonics, assymetrical distortion.

Figures 1(C) and 2(C) show only two of the possible waveforms resulting from distortion. These are by no

means the only ones. An entire catalogue of distortion waveforms would be too lengthy to include in this paper.

In practical PA amplifier maintenance, the 2nd, 3rd, and 4th harmonics usually are the most troublesome distortion components. The 2nd harmonic may be eliminated, or at least reduced considerably, simply by employing a pushpull output stage in the amplifier. Distortion arises from tubes; improperly selected resistors, capacitors, choke-couplers, or transformers; mismatched input or output circuits; poorly designed circuits; worn or de-

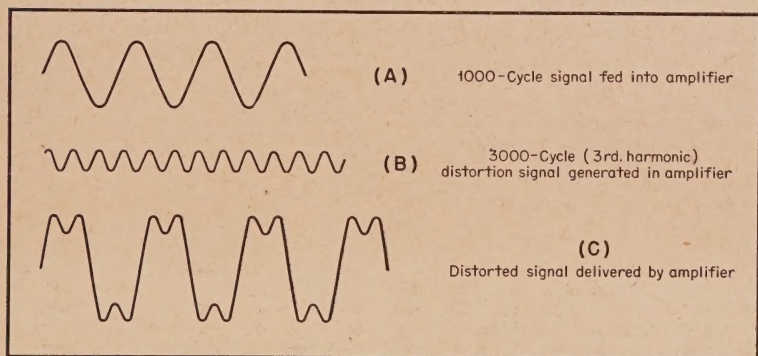


Fig. 2. Pronounced 3rd. harmonic distortion.

fective components; defective loudspeakers; and similar causes. Tube tables give the various distortion percentages which may be expected from tubes. For example: from tube tables, the total harmonic distortion for cathode-biased type 6A3 tubes in pushpull is found to be 5.0%. Type 6L6 as a single-tube class-A₁ 300-volt amplifier with cathode bias is listed at 11%.

From the foregoing discussion, it is seen that distortion is caused by harmonics which are generated within the amplifier and which combine in the output signal with the original fundamental frequency. These harmonics have various strengths but ordinarily have lower voltage amplitudes than the fundamental. The 2nd harmonic has one voltage amplitude, the 3rd harmonic another, and so on.

A distortion measurement consists of either (1) measuring the voltage of each individual harmonic separately, determining its percentage with respect to the fundamental, and totaling the percentages **in the proper manner**; or (2) measuring the total harmonic distortion directly.

Each separate harmonic percentage may be found in the following manner:

$$(1) D = \frac{E_2}{E_1} \times 100$$

Where D is the harmonic distortion at a single harmonic (such as the 2nd)

E_1 is the voltage of the fundamental signal only

and E_2 , the voltage of the harmonic only.

Each separate harmonic percentage must be calculated in the same manner separately if we use the first method of distortion measurement. It is important to note, however, that we cannot simply add up these separate percentages to obtain the total distortion. Instead, we must square each percentage, add the squares, and find the square root of this sum. This square root then will indicate the total dis-

tortion percentage. The following formula is employed:

$$(2) D = \sqrt{D_2^2 + D_3^2 + D_4^2 + D_5^2 + \dots + D_n^2}$$

D is the total distortion percentage. D_2 , D_3 , D_4 , and D_5 are, respectively, the separate percentages of the 2nd, 3rd, 4th, and 5th harmonics. D_n is the percentage of any other harmonic (such as the 6th) which might have been discovered and measured. D_2 , D_3 , D_4 , D_5 , and D_n each must be calculated according to Equation (1).

In order to measure each harmonic voltage separately, a wave analyzer is needed. The wave analyzer is an instrument which may be tuned separately, like a radio receiver, to each audio harmonic and which will indicate the voltage of each. The wave analyzer is an expensive laboratory instrument which seldom is found in amplifier service shops. A second, simpler and less expensive instrument, the **distortion analyzer**, will perform the same task, provided a single fundamental test frequency is employed. The **sonic analyzer**, also a laboratory caliber instrument, is of the nature of an automatically-tuned wave analyzer. It pictures the entire audio spectrum on a cathode ray screen, showing the fundamental voltage and each harmonic voltage as peaks or pips of different height.

Another way of checking individual harmonics is to use an oscilloscope. This method involves getting a picture of the output signal (similar to Figure 1-C or 2-C) on the scope screen and measuring the height of each harmonic, as well as that of the fundamental. The oscilloscope method is much more complicated than it would seem to be, since the distortion patterns often are not as clearly defined as those shown in Figures 1(C) and 2(C). Also, the oscilloscope method is a time-consuming procedure which many servicemen assert cannot be used profitably.

Most busy servicemen prefer to check the total distortion, rather than that of separate harmonics. This type of test may be made quickly and will show the complete distortion picture.

A simple apparatus setup for measuring total distortion is described later in this article under the heading **Quantitative Distortion Test**.

Qualitative Tests of Distortion

A qualitative test of any kind involves no figures but usually serves only to establish the presence or absence of some factor. The qualitative distortion test shows simply whether or not distortion is present and in which stage it originates. The common qualitative tests, which may be made in the service shop or "on location" are described separately in the following paragraphs.

Ear Appraisal. Some idea of distortion can be gained merely by listening to an amplifier. If the amplifier output signal does not sound natural, something is wrong. Distortion is pretty sizeable, however, before the ear even recognizes it (the ear will tolerate a total distortion up to about 5%). Spotting distortion by ear depends upon so many uncertain factors, such as mental and physiological conditions, that even the trained ear must be regarded as an unreliable instrument.

Plate Current Check. In a class- A_1 amplifier, the plate current remains steady when the signal is applied, if there is no distortion. Any shifting of the zero-signal plate current indicates distortion. The plate current test may not be applied to class- AB_1 , AB_2 , and B amplifiers, however, since the maximum-signal plate current in each of these types normally is higher than the zero-signal current. To locate distortion by this method, it is not necessary to break the plate circuit and insert a milliammeter. The same result may be obtained by connecting a high-resistance d.c. voltmeter across the cathode resistor of the amplifier stage under test. The cathode voltage should not change when the audio signal is applied or removed.

Grid Current Check. When a class- A_1 or AB_1 amplifier is operating properly, without distortion, no grid cur-

rent flows. Any tests showing the flow of grid current reveals distortion. A simple test for grid current may be made with an electronic d.c. voltmeter. Simply connect the meter from control grid to ground in the amplifier stage under test. A negative voltage, due to the bias voltage is obtained. This voltage, like the plate current, will not fluctuate unless distortion is present. This test, like the preceding plate current test, can be applied only to class- A_1 and AB_1 amplifiers, since a certain amount of grid current normally flows in class- AB_2 and class-B stages.

Oscilloscope Test. The cathode ray oscilloscope is very useful in tracing out and localizing distortion in the various stages of an amplifier. Particular advantages of this instrument are (1) its wide frequency response, (2) high input impedance, and (3) ability to reproduce waveforms. Two methods of checking with an oscilloscope are described in the following paragraphs.

Method 1

(1) Set the oscilloscope for sine wave patterns (that is, switch-on the internal sweep oscillator) and connect a good sine-wave audio oscillator to the input terminals of the amplifier under test. Place the amplifier and oscillator into operation, along with the oscilloscope.

(2) Connect a test prod with shielded lead to the vertical amplifier input terminals of the oscilloscope. Connect the ground (common) terminal of the oscilloscope to the amplifier chassis or B-minus terminal. Touch the test prod first to the amplifier input terminal and adjust the oscilloscope sweep and amplifier controls to give 2 or 3 **stationary** cycles on the screen.

(3) Touch the test prod successively to the control grid terminal of each stage in the amplifier under test. At no point should the smooth sine-

wave pattern become distorted. A common indication of distortion (usually caused by overdriving the stage under test) is shown in Figure 3(A). Here, the top of each peak is flattened off, resembling a square wave.

(3) Distortion is indicated whenever the line or the ellipse loses its smoothness, becoming broken, ragged, or fuzzy, as in Figures 3-D and 3-E.

Quantitative Distortion Test

Figure 5 shows a simple circuit for

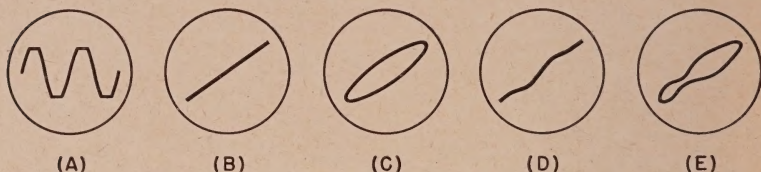


Fig. 3. Oscilloscope patterns for qualitative distortion.

Method 2

(1) Set up the oscilloscope, amplifier, and audio oscillator as described in the previous test, except do not use the internal sweep of the oscilloscope. Instead, connect the horizontal amplifier input of the 'scope to the audio oscillator (See Figure 4).

(2) If there is no phase shift within the amplifier under test, a smooth slanting line will be seen on the screen (Figure 3-B) when the test prod is touched to any signal point in the amplifier. In most instances, however, there is some phase shift and a smooth ellipse (Figure 3-C) will be obtained instead of the line.

making quantitative measurements of total amplifier distortion. This setup may be used to check a complete amplifier or a single amplifier stage. Because of its function, the circuit often is referred to as a **harmonic totalizer**.

The theory of operation of the device is simple: A bridged- T null network is formed by the iron-core choke, capacitors C_1 and C_2 , and resistor R_2 . The network's constants have so been chosen that the null frequency equals the fundamental test frequency. This means that the network will remove the fundamental frequency from a distorted wave but will permit all of the harmonics to pass. It is then only

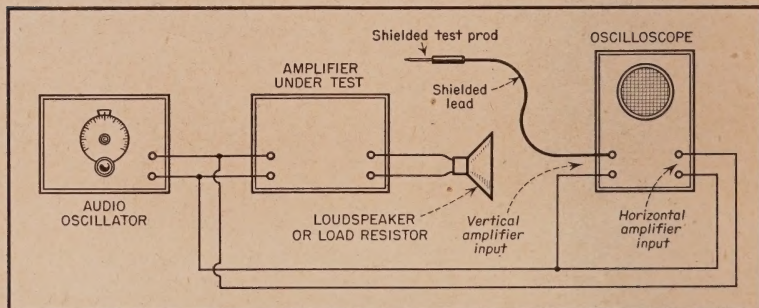


Fig. 4. Showing how 'scope horizontal amplifier input is connected to audio oscillator.

necessary to measure the total harmonic (distortion) voltage (which is the voltage left after the network has removed the fundamental) and to compare this voltage with the full signal voltage. A high-input-impedance a. c. vacuum tube voltmeter or an

minals of the amplifier under test, and set the amplifier gain control for desired power output. (2) Connect the input terminals of the distortion checker to the loudspeaker voice coil or amplifier load resistor. (3) Throw switch S to its right-hand position

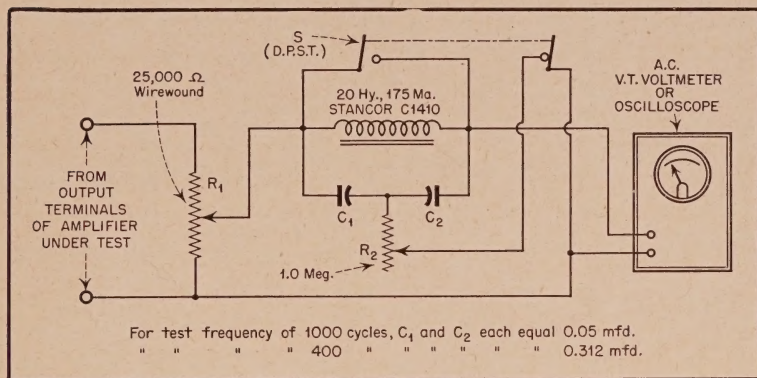


Fig. 5. Simple total-distortion meter.

oscilloscope may be used for the voltage measurement.

After the instrument is completed, it is given its initial adjustment in this manner: (1) Connect a sine-wave audio oscillator to the input terminals of the distortion test circuit. (2) Set the oscillator to 400 or 1,000 cycles (depending upon which values have been chosen for C₁ and C₂). (3) Throw switch S to its left-hand position. (4) Set potentiometer R₁ to its top (full-voltage) position. (5) Adjust rheostat R₂, while at the same time tuning the oscillator carefully, until the lowest deflection of the voltmeter or oscilloscope is obtained. The network now is nulled, and rheostat R₂ ordinarily will not need to be touched again.

To use the distortion checker: (1) Connect the audio oscillator (set to the null frequency) to the input ter-

(this short-circuits the choke and disconnects rheostat R₂, thereby permitting the entire signal voltage to reach the voltmeter). (4) Adjust potentiometer R₁ for full-scale deflection of the meter or a full-screen pattern on the oscilloscope screen. Record this voltage as E₁. (5) Without touching any of the other controls, throw switch S to its left-hand position (the network now is thrown into the circuit and will remove the fundamental frequency) and read whatever voltage remains at null. Record this voltage as E₂. (6) Find the total distortion by means of the following formula:

$$(3) \quad D\% = \frac{E_2}{E_1} \times 100$$

The distortion checker may be built into a small box or case about the size of the conventional serviceman's multimeter.



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N O T I C E

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Editor,

C-D CAPACITOR.

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FOR SALE—S40A rec., less than 100 hours use, \$75; Solar capacitor (CC-1-60) analyzer, Al cond., \$30; Triplett tube tester, mod. No. 1612, excellent cond., \$30. Cloyd's Radio Shop, 454 S. 3rd St., Hamilton, Ohio.

WANTED—Several P-8-41 Cannon output receptacles (8-contact female) from surplus dynamotor PE-103-A. Please name your price. Will answer all replies. Ed Bruns, 28 Hill St., Floral Park, N. Y.

FOR SALE OR TRADE—Have large number of back issues of Service magazine and Communications magazine. Also large file of C-D Capacitors. If interested, write—Paul H. Prokes, 9216 S. Menard Ave., Oak Lawn, Ill.

WANT—Floor model combination console cabinet for large rec. and changer. Also need Precision tube tester and or model EV-10 VTVM, SW rec., condition not important. Glenn Watt, Chanute, Kansas.

SWAP—\$25 camera bag, 35mm filters, 100' 35mm super xx film, and other articles for radio equip., or what have you? Douglas Powell, Box 595, Spencer N. C.

TRADE—New Seeburg record changer, never used, for late model tube tester. Give full description. Also many hard to get tubes for exchange. Sam Berenblum, 417 Greenwich Ave., Greenwich, Conn.

TRADE—United Television Laboratories, Inc. course on radio fundamentals and servicing; Ghirardis' manual of "Modern Radio Servicing" for other radio course. James W. Shope, 944 E. Chestnut St., Jeffersonville, Ind.

WANTED—Evening and Saturday work in Brooklyn, N. Y. Experienced radio serviceman on all types of radio and electronic equipment. David N. Nadel, 981 Sutter Ave., Brooklyn, N. Y.

FOR SALE—Echophone EC-1 rec. in good shape, \$20 post paid. Also will send diagram of same with set. A. W. Jaeger, 719 Lowell St., Ypsilanti, Mich.

FOR SALE—EEA field telephones, slightly used, in perfect condition. \$18 per pair, in leather or canvas case with slings. H. J. Lewis, 548 - Brompton, Chicago 13, Ill.

FOR SALE—Service shop selling everything. \$60 Electronic Designs electronic VOM with probe, \$45; \$42.50 ATR 6V d.c. power supply, \$20; stock of new tubes, 60% off; new 5", 6" speakers, \$1.25 each; amplifiers; pickups; other items. The Radiotician, 5639 University, Chicago, Illinois.

WANTED—6 volt power pack for auto radios. State price and particulars. J. W. Acampa, 177-40 119 Road, St. Albans, L. I., N. Y.

WANTED—Would like to hear from someone who has built the magnetic tape recorder described in Radio News for February, 1948. Andre's Radio Repair 122A N. Quinsigamond Ave., Shrewsbury, Mass.

WANTED—Control head for 1939 Chevrolet auto radio (Philco No. C-1452) with or without cables. Dave Boord, 90-40 148 St., Jamaica 2, N. Y.

SELL OR TRADE—BC367 interphone amplifier (6V6's); Motorola Dual Vibrapacks, 6V input, 540V at 160MA output or 300V at 300MA; crystal pickup and arm; variable reluctance pickup; miscellaneous tubes and parts. Want camera accessories. A. Zambakian, 914 Nelson St., Staunton, Va.

TRADE—Various kinds table model radios. Want 22 cal. revolver, 6" barrel, brake down, 8 or 9 shot, small frame pre-war model. A. H. Alderson, Spring Hill, W. Va.

FOR SALE—Model P Porta power supply, \$5; model O.C. Clough-Brengle oscillator, less leads, \$15. Martin Straun, Route 3, Lancaster, Ohio.

FOR SALE—Presto K8 recorder and PA system practically new. Positively guaranteed. Cost \$389, sell for \$250. R. E. Johnson, 1010 Congress St., Schenectady, N. Y.

WANTED—Second hand enlarger in good condition. Joseph Snider, Lincoln Rd., Lincoln, Mass.

FOR SALE—Back issues of QST, .15 cents a copy. Also misc. radio parts. Box 1, South Coventry, Conn.

FOR SALE—Riders' Manuals, 1 to 5 abridged, 6 to 15, in original wrappers, some not used 20% discount, FOB. Also professional model 66 Triplett tube checker, perfect. Radio Electric Shop, B3, Belleville, Ark.

WANTED—BC 348 Q communications rec. preferably with speaker, used, but in good condition for 110V ac. State minimum price acceptable. D. Landesberg, 179 Marcy Ave., Brooklyn, N. Y.

WANTED—Complete set of Riders' Manuals or any part thereof. William Nichols, Carmel, N. Y.

FOR SALE—Mobile transmitter, RCA, FM, 30 watts output, new, complete with control unit, dynamotor, cabling and tubes. Jose Alvarez, 2602 Germantown Ave., Philadelphia 33, Pa.

SELL OR TRADE—BC603-604 amateur FM transmitter and rec. combination, \$25; complete set radio servicing instruments, radio engineering correspondence course cheap. Want full size good typewriter, mimeograph, adding machine. K. H. Stello, 3619 W. 102nd St., Inglewood, Calif.

FOR SALE—Radio News, Radio Craft, various, 1923-1935, write for copies available; National FBX-A, 6 pair coils, needs rewiring, best offer; Buescher E-flat sax, repadded, fine shape, \$75. Samuel S. Potter, Star Route, Mill Creek Road, St. Augustine, Fla.

FOR SALE—New Temple portable 6 tube set, reg. \$49.50, sale \$37.50, less batteries; RCA Station Allocator, model 171, \$14.95; 6V PA system, \$35; 2 used auto radios, cheap. Want TV set with channel 4. Ben's Radio Service, Nash Road, North Tonawanda, N. Y.

FOR SALE—Engineering samples of plastic table model radios. Thoroughly reconditioned by factory technician. Carries new radio guarantee, at \$10 and \$15. T. Popel, 1223 Elm Ave., Brooklyn 30, N. Y.

WANTED—80 or 40 meter V.F.O. Millen R9 for 10 and 20 all band TV booster. Alfred Freitag, 1437 Patapsco St., Baltimore 30, Md.

WANTED—Used 10" speaker from Philco floor model 118. Must be O.K. and ready for operation. G. E. Eggleston, Box 524, Geneva, Minnesota.

FOR SALE—G.E. tube tester, model TC-3, like new, \$30; code practice oscillator, new, \$8; Weston analyzer, model 577, \$15; Fada 6 tube table radio, model 652, perfect, \$20. J. Willis, 61 Hayes Lane, Wilkes Barre, Pa.

WANTED—1 piece hearing aid, stencil duplicator. Trade portable and auto radios, test equip. tech. books and some cash. Eugene M. Campbell, 824 Short Street, Litchfield, Ill.

WANTED—Chart for Weston tube checker, No. 682, type 2. Will swap for what you need or cash. Ben Nettler, 137 Haven Ave., N. Y. 32, N. Y.

FOR SALE—Radio books; Electrical Engineering, U.H.F. Techniques, Mathematics for Electricians and Radiomen, Principles of Radio Engineering, College Mathematics, Supreme Publications circuit diagram manuals 1926 to 1942 inc. All for \$6 prepaid. John J. Sturek, 2621 F St., Omaha 7, Nebraska.

SELL OR SWAP—Hammarlund Super Pro, with 6' high steel ham rack, A1 condition, like new. Will consider good television rec. 52" screen or larger. Describe fully. Oliver F. Klein, 2235 N. 39 St., Milwaukee 8, Wis.

FOR SALE—Atwater Kent 76, new tubes, power transformer, volume control, A-1 playing condition, \$25. Midwest 18 tube radio in good condition, \$30. S. E. Graycar, 144 Columbia Ave., Phoenixville, Pa.

WANTED—Transmitter, such as, Meck T-60, Hallicrafter H-T6, H-T17, UHX-10. Samkoisky, 527 Bedford Ave., Brooklyn 11, N. Y.

FOR SALE—Tubes and sig. gen. Write for list. Paul Blum, 366 Hunterdon St., Newark 3, N. J.

FOR SALE—Vomax VTVM, in new condition, \$48. Douglass G. Phelps, 10 Smith St., Sidney, N. Y.

WANTED—1SB6, 3B5, 1SA6 Emerson radio tubes. Have other tubes to trade or will pay cash. National Radio Service, 1823½ Dexter Ave., Portsmouth, Ohio.

WANTED—25B8 tube. Will pay list price. Herb's Sales and Service, 130 N. Durfee Ave., Pico, Calif.

FOR SALE—Complete radio repair shop, finest tools, test equip, tubes, sacrifice at inventory. Must be sold as unit. Reason for sale, "health." Robert R. Jackson, 10 Park St., Wapakoneta, Ohio.

FOR SALE—7" television set, complete with tubes, but without cabinet, \$75. New Janette rotary converter, dc to ac, 300W, \$75. 5BP4 CRT, \$3. K. Kelmis, 153 W. 66 St., N. Y. 23, N. Y.

FOR SALE—1 Electronic design vacuum tube volt-ohm meter, model 100; 1 Trip-lett tube tester, model 2413. Both good as new. Robert B. Vick, 125 Athens Pike, Etowah, Tenn.

FOR SALE—Weston tube tester, model 777, portable type, like new. Take first \$45 offered. Lester Yarger, 701 Wash-tenaw St., Ypsilanti, Mich.

TRADE—5,400 foreign stamps, all different, for tube tester, test equip, recorder, portable radio. W. Troppman, 532 So. Mission St., Wenatchee, Wash.

FOR SALE—Hard to get radio tubes, new and in cartons. Send for list. Joseph Anderson, Box 47, New Sweden, Me.

SELL OR SWAP—Solovox in very good condition; audio sig. gen, worth about \$400; new Dumont 5" scope; several amp. 15 to 35 watts; Hickok 530 tube tester; Winchester 52 target rifle; and many other items. Want RCA Chanalyst in good condition. Gerald Hess, 15 Park St., Moravia, N. Y.

WANTED—National or Hammarlund rec. with crystal filter and S meter. Age no object, but must be in excellent condition. E. A. Whitnah, Route 1, Box 21, Little Rock, Arkansas.

FOOR SALE—Hammarlund HQ129 rec., like new, \$140. W2RVD, 15 Tuxedo Ave., New Hyde Park, N. Y.

FOR SALE—Scott chippendale cabinet, \$100; Laboratory audio oscillator, \$50; Scott rec. S4R-H, \$75; Altec 603 speaker, \$40. Would exchange in part for Natl. FM tuner and Stephens P52A speaker. C. R. Evans, Birch Lane, Mountainside, N. J.

FOR SALE—Assort. of tubes worth \$165, resistors, condensers, electrolytics, parts, Precision E-200-C sig. gen., Simpson 305 tube tester, DeForest training course in Radio and Television. All for \$225 cash. Robert Baribeault, 20½ No. A St., Taftville, Conn.

FOR SALE—Supreme Model 599, like new. Tube, battery, and set tester, \$40. Harry Altman, 72 Bay 37th St., Brooklyn 14, N. Y.

FOR SALE—50 each of following tubes: 1R5, 1S5, 3Q4, 57 cents each, new in orig. cartons. Minimum order, 2 tubes. Thomas Marcelle, PO Box 1304, Milwaukee 1, Wis.

TRADE—Over 500 foreign coins and banknotes, over 50 different countries; Packard electric shaver. -Want television kit, test equip., etc. Ben Prucnal, 233 Gramercy Ave., Toledo 12, Ohio.

FOR SALE—BC 342 N Signal Corp. rec., with self contained 110V ac supply. Guaranteed perfect working condition, \$69. Andrew A. Attard, 92-31 Gettysburgh St., Bellerose, Long Island, N. Y.

FOR SALE—Hallicrafter's power supply, type RA63-A, converts 110V ac to 6 to 8 volts dc at 10 amps, and 10 to 14V dc at 12 amps. Complete with cables, \$18. Andrew Valentino, 57-13 69th St., Maspeth, N. Y.

FOR SALE—Meissner FM tuner, model 8C, like new, \$35. Harold Hillison, RFD 3, Amboy, Ill.

FOR SALE—BC 412 Army oscilloscope, unconverted, \$40 FOB. Bernard Soroka, 403 N. Collington Ave., Baltimore 31, Maryland.

FOR SALE—RCA 955, 956, 9005, 9004 acorn tubes matched; high fidelity output trans.; Weston model 301, 0 to 50 micro. amp. meter; Amphenol 6AF6G magic eye assem.; Weston wire wound resistors. J. R. Holloway, Box 133, Haddonfield, N. J.

FOR SALE—Modulator BC 669A (6C5 to four 6L6) and power supply PE 110C for best offer. All inquiries answered. Antonio L. Oliveira, 94 Potomska St., New Bedford, Mass.

TRADE—Patterson PR10 rec., 540 to 2,100 kc, with 10" heavy duty speaker in good condition. For Meissner or Brewster FM tuner, 88 to 108mc, good portable typewriter or rotary photo print washer. Joe Latham, 170 No. 2nd Ave., Upland, Calif.

FOR SALE OR TRADE—NRI Radio service course, 40 lessons, good condition, 1939 edition; 1 tube leakage and short tester, pocket size, test prods and neon globe. \$20 for all or trade of equal value. R. S. Tourtellotte, 624 So. Wyoming, Butte, Mont.

SELL OR TRADE—Audel's Radioman's Guide, Coyne Electrical and Radio Ref. Encyclopedia (3 vols.), ARRL Handbook year 1943, and MYE Technical Manual. Want low priced Ranger 432-A or Superior 1240 tube tester. C. E. Boon, 5 Spring Hollow Ave., Roanoke 12, Va.

FOR SALE—Triplett vacuum tube volt-meter, model 1250, used very little. First reasonable offer takes it. L. S. Maxfield, PO Drawer 2190, Hartford 2, Conn.

FOR SALE—Triumph 820 3" scope, \$25; Regulated power supply, 350ma, 150-470V with 2 meters, \$35; Weston output meter, \$12.50; Weston OQ tube checker, \$35; 35W PA system with mike and spkr., \$45. Paul Krikorian, 419 9 St., Union City, N. J.

FOR SALE—Riders' Manuals, 6, 7, 8, 9, 10, 12, \$70, you pay postage; Dynamic Electronometer tube tester, \$37; National Radio Institute Radio Course, \$15; Cornell Dubilier capacitor analyzer, \$35; All wave all purpose tester, \$30. Francis Sheloski, 339 Maffett St., Plains, Pa.

SELL OR TRADE—Meissner Analyst, complete with cables, manual, good condition. Want VTVM, communications rec. or woodworking power tools. Make offer. P. L. Wilder, Jr., Attapulugus, Ga.

FOR SALE—RCP Multimeter, model No. 447, excellent condition, \$15. Edward Tanrath, 3151 W. Monroe St., Chicago 12, Ill.

FOR SALE—Tube tester; VTVM; Coyne radio books; Sams' Photo Diagrams, 1 to 10; Riders' No. 1; tubes; speakers; other books and courses; write for list and prices. Forrest Burnham, 1096 E. 7th St., Chico, Calif.

FOR SALE—Supreme model 89 tube tester, \$15; Test-Rite model B-45 sig. gen., \$20; Radio its Co. VOM, \$15. All in good condition. Harold A. Moon, 611 Oneida St., Fulton, N. Y.

SELL OR TRADE—BC-459, -696 converted, dual rack, \$30; Brentwood 14W PA amplifier, \$30; complete SCR-274N command set, \$35; 2 new 872's, 50W sockets, \$5; 2 G.E. pyranol filters 2mf-5000V, \$15. Need R9'r millen variarm, G.I. dual recording unit. M. Bardfield, 4 Brinsley St., Boston, Mass.

SELL OR TRADE—Vomax 900, like new, \$40; Sparks 905 sig. tracer, remodeled at factory, \$30; 20W sound projector amplifier, with all, direct, mike and stand, long cables, portable, \$50. Want Precision E-200C and Precision EV10 VTVM. Franklin C. J. Slay, 243 West 107 St., New York 25, N. Y.

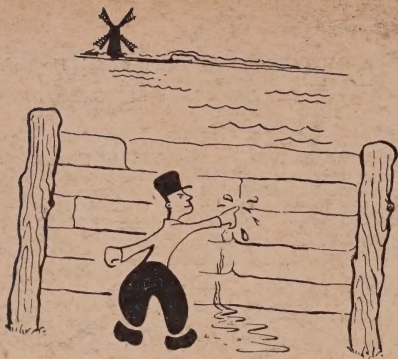
FOR SALE—Tube tester, model 450, perfect condition, with instructions. Test latest type tubes, \$24.50. 15" Cinda-graph speaker, never used, \$12. Both postpaid. Casimer Kusak, 111 Hirschbeck St., Buffalo 12, N. Y.

FOR SALE—Hickok 156 Traceometer, \$100; Hickok 305 scope, \$100; Hickok 534 tube tester, \$85; also misc. parts. Excellent condition. Capt. A. W. Davis, Braniff Airways, Dallas, Texas.

WANTED—Good used NRI resistor-condenser tester, model 111, and Waterman Pocketscope, model S-10A. Fallaw's Radio Service, 20 Gordon, Clinton, S. C.

SWAP—Brand new Hickok model 203 VTVM for Solar model C-F exometer and \$50. Sporna Radio Service, Escatawpa, Ala.

FOR SALE—SX28A Hallcrafters rec., with speaker in good condition, reasonable price. Frank Tschappat, 3335 N. High St. Columbus 2, Ohio.



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DAVID GNESSIN of Columbus, Ohio

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David writes: *"Here's a CUB type made by Cornell since 'way back . . . came from an old Grebe set. The wax' never even ran a little bit in the terrific heat. This capacitor is as old as any I've ever seen in ANY radio equipment in use today."*



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